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An Research on Electrical Vehicle'S Charge-Discharge Behavior Based on Logit Model

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Abstract

Electric Vehicle is the future trend of the automobile industry, and the energy exchanging between the electrical vehicles and the grid through the vehicle-to-grid (V2G) technology becomes possiable. V2G leads to a rapid load growth effecting the benefit of the grid, which wasn't discussed. The charge and discharge model of the electrical vehicles is discussed using the multinomial logit model based on the discrete choice theory, then preliminarily evaluates the effects of economic benefit both on the motorist and the grid. Finally, suggestions on period division and electricity pricing for charge and discharge of the electrical vehicle are given.

Keywords:electric vehicle; vehicle-to-grid; charge and discharge model; logit model; benefit.

1.Introduction

Our country's automobile industry is being in the swift development the stage. Concerining about oil availablity and air quality issues related to vehicle emissions,electric vehicle (EV), which can realize zero emissions and low noise, have brought new turning point for the automobile industry. To 2012, there will be 10% new production vehicle is the energy conservation and new energy vehicle.

It becomes possible that the energy exchange between the electrical vehicle and the grid through the vehicle-to-grid (V2G) technology[1],which is an impotant part of the smart gird. The basic concept of vehicle-to-grid power is that electric-drive vehicles provide power to the grid while parked and charge during low demand times, so that electric vehicles can be viewed as distributed generation and also distributed load[2]. According to statistics, the vehicles are at stop trips condition for 90% of the time, during which vehicles can connect with the gird and exchange energy[3]. The rapid growth of the electrical vehicle brings the new challenge and opportunity for the grid company. The electric vehicle charging stations having been running is the important section of the development of the EV. And the charge price is established by referring to the peak and valley price of commercial[4]. In this paper, considering vehicle-to-grid(V2G)technology and the exisiting peak-valley TOU power price mode, we discuss the charge-discharge behavior of the EV, preliminary evaluation its self benefit and the impact on

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the grid.

2.Electric vehicle's charging model

It is assumed that the existing cars are replaced by the same type of electric vehicle, and this kind of electric vehicle's related parameters are the existing electric vehicle's mean parameters. In the starting state of all the batterys are full, charging-discharging model is researched.

After the battery fully charged, the driving time of the electric vehicle depends on the daily mileage. Assuming that variable X representing the driving time meets normal distribution with the parameter variable (μ,σ^2), the distribution probability about the driving time of the electric vehicle is calculated below,

$$P(X=N)=\Phi\left(N+1-\mu \middle/ \sigma\right)-\Phi\left(N-1-\mu \middle/ \sigma\right) \quad (1)$$

Where N is the days electric vehicle can travel. If $N\leq 1$, electric vehicle needs to be charged every day.

Multinomial logit model based on the diecrete choice theory is widely used to solve the problem about multi-alternatives choice, which is also called effectiveness maximization model[5]. There are two suppositions as below: the motorist is usually considered as "the rational manager"[6]; the motorist always chooses the mode bringing him the maximum benefit. For each selection, a degree or utility value is determined by observable and unobservable factors. And then probability analysis of the motorist's section behavior is taken.

Assume electric vehicle fully charged needs w kWH, if it can drive N days, daily consumption of electricity is w/N kWH. Making sure of one normal driving day, motorist can sell part of the electricity. If the daily driving consumption is defined as a unit, motorist sell i units, namely motorist sell electrical consumption for i days. And suppose the electicity is sold in the form of a whole, denoted the i-options. There are altogether N choices, denoted by A_N. When motorist makes the choice, three observable factors have to be considered: the economic benefit obtained from the charge-discharge behavior; convenience defined by the driving days after being sold out part of electricity, and the more the number of days is, the greater convenience will be; and the car life. Considering the existence of unobservable factors, the utility function is formed,

$$\begin{cases} U_{Ni}\left(B_{Ni},E_{Ni},I_{Ni}\right)=V_{Ni}\left(B_{Ni},E_{Ni},I_{Ni}\right)+\varepsilon_{Ni}\left(B_{Ni},E_{Ni},I_{Ni}\right) \\ V_{Ni}\left(B_{Ni},E_{Ni},I_{Ni}\right)=a_N B_{Ni}+b_N E_{Ni}+c_N I_{Ni} \end{cases} \quad (2)$$

Where $U_{Ni}(B_{Ni},E_{Ni},L_{Ni})$ is the utility function of the i-options, $V_{Ni}(B_{Ni},E_{Ni},L_{Ni})$ is the deterministic component of the utility function consisting of observable factors, $\varepsilon_{Ni}(B_{Ni},E_{Ni},L_{Ni})$ is the uncertain item of the utility function consisting of observable factors, B_{Ni} is the benefit, E_{Ni} is the residual driving days, L_{Ni} is the car life. These parameters belong to i-options.

To determine the parameters of the utility function, the analytic hierarchy process (AHP) is used, which is a multi-objective decision making theory combinating of qualitative and qunantitative[7]. It decomposes a complex problem into a multi-level hierarchic structure of objective to represent judgments in the form of paired comparison. A ration scale of relative magnitudes expressed in priority units is derived from each set of comparisons. An overall ratio scale of priorities is then synthesized to obtain a ranking of the alternatives[8].

The selection probability is derived from the utility maximization theory as below[9,10],

$$P_{Ni}=\exp\left(V_{Ni}\right) \Big/ \sum_{J\in A_N}\left(V_{Nj}\right) \quad (3)$$

Where P_{Ni} is the probability that motorist decide to sell electrical consumption for i days.

If motorist sell i units of electicity, the remaining number of traveling days is *N-i*. Tow hypothesis are proposed: the probability about the day being chosen to sell the electricity satisfies uniform distibution; and the probability about the hour of the peak period being chosen to sell the electricity also satisfies uniform distibution. At these assumptions, the probability of selling electricity at the T-hours of the d-days and the total number of sold electricity are calculated,

$$P_N(T|d)=1/a(N-i) \quad (T=1,2,\cdots,a;d=1,2,\cdots,N-i) \tag{4}$$

$$Q(T|d)=\sum_{N=1}^{l}\sum_{i=0}^{N} iw/_N ZP(X=N)P_{Ni}P_{Ni}(T|d) \tag{5}$$

Where a is the total number of the hour in the peak period, Z is the vehicle number, l is electric vehicle's longest driving days after being fully charged.

3.Electric vehicle's discharging model

Based on the assumption that the charging time of the single vehicle is H hours and the same amout of power needed per hour, an formula is derived[11].

$$W(t)=w/_H \tag{6}$$

Where t is the charging time, if $t<0$ or $t>H$, $W(t)=0$。

There are Y vehicles need to be charged at the d-days. Assump all electric vehicles have to start in the beginning of an hour and complete in the valley period. If the valley period continued m hours, electric vehicle shouldn't to be charged later than the $(m-H)$hours. The total power required at the d-days can be obtained under the assumption of electric vehicle charged at any allowed hour with the same probability.

$$Q_z(t)=\sum_{n=1}^{m-H}\left(\sum_{N=1}^{l}Y_{Nd}\right)1/_{m-H}W\left[t-(n-1)\right] \tag{7}$$

Where Y_{Nd} is the number of vehicles, of which the original driving day is N days, charged at the d-days. n is the n-hours of the valley period, $1/(m-H)$ is the probability of starting charging at the n-hours.

4.Benefit assessment of the charge-discharge behavior

The benefit gained from the single charge-discharge behavior for one vehicle is formulated.

$$C_{Ni}=i\,w/_N P_f-wP_g \tag{8}$$

Where C_{Ni} is , P_g is charging price corresponding to the valley price for commercial electricity, P_f is electricity sales price corresponding to the peak price for commercial electricity.

If all load remain the same except the charging and discharging load, the increment of benefit related to grid company is calculated.

$$\Delta C_2=Q_1P_g-Q_2(P_f-P_c) \tag{9}$$

Where Q_1 is the total consumption of batterys charging in the d-days, Q_2 is electricity sales from electric vehicles to grid, P_c is the average price of the purchase of electricity plant.

5.Analysis of an example

Electric vehicles over 3 hours on one charge, the power consumption of 60 kWH, can travel 150 km. Private car ownership in a city is 1.098 million, and the daily average vehicle mileage is 49 km. Then the distribution table about the driving days is obtained. By AHP to determine the calibration parameters of the utility function, the probability distribution table of electricity sales typed by driving days is showed as below.

TABLE I. DISTIBUTION OF THE ELECTRIC VEHICLES' DRIVING TIME

N	<=1	2	3	4
The number of cars	4420	479121	604154	10306

TABLE II. PROBAILITY DISTRIBUTION ABOUT CHOUSING THE ELECTRICITY SELLING OF THE ELECTRIC VEHICLES IN LOGIT MODEL

i	0	1	2	3
P_{2i}	0.5228	0.4772	——	——
P_{3i}	0.2556	0.3913	0.3531	——
P_{4i}	0.3293	0.2355	0.1642	0.2710

Based on the selection probability ,according to (5)(7), we obtain the following load curve. Under existing division of the peak-valley periods, the large number of charge-discharge behaviors make a significant incrrase in the valley load hours of electricity, forming a new peak. The actual peak load from 7 am to 11 am only shows the low load levels. Although electric vehicles supply a large number of power to the grid in that period, the peak slipping function is not obvious.

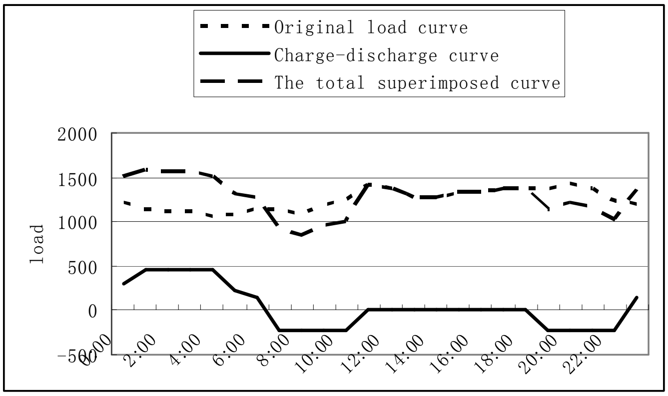

Fig.1 The daily load curve of whole city in charge and discharge model

TABLE III. ECONOMIC BENEFIT ABOUT THE ELECTRIC VEHICLE'S CHARGE AND DISCHARGE MODEL IN PLENTIFUL WATER PERIOD

i	0	1	2	3
C_{1i}	-21.814	——	——	——
C_{2i}	-21.814	17.89	——	——
C_{3i}	-21.814	4.655	31.125	——
C_{4i}	-21.814	-1.962	17.89	37.742

TABLE IV. ECONOMIC BENEFIT ABOUT THE ELECTRIC VEHICLE'S CHARGE AND DISCHARGE MODEL IN DROUGHT PERIOD

i	0	1	2	3
C_{1i}	-28.213	——	——	——
C_{2i}	-28.213	24.29	——	——
C_{3i}	-28.213	6.788	41.79	——

C_{4i}	-28.213	-1.962	24.29	50.54

Charging and discharging price is based on the city's commercial peak-valley TOU power price, calculated the benefit according to a single electric vehicle's charge-discharge behavior is shown in table 3,4.The cost of driving electric vehicle is far less than traditional fuel vehicle. If the owers sold part of the power which can offset the costs and generate additional revenue. Seen from the tables, the largest gain is 37.742yuan per time in the plentiful water period and 50.54 yuan per time in drought period. In the long run, the benefits are considerable.

TABLE V. GRID COMPANY'S INCREMENT OF INCOME IN PLENTIFUL WATER PERIOD

d	**1**	**2**	**3**	**4**
ΔC_2	-982.337	83.462	-640.185	90.865
d	5	6	7	8
ΔC_2	-982.337	425.613	-982.337	90.865
d	9	10	11	12
ΔC_2	-640.185	83.462	-982.337	433.017

TABLE VI. GRID COMPANY'S INCREMENT OF INCOME IN DROUGHT PERIOD

d	**1**	**2**	**3**	**4**
ΔC_2	-1282.806	95.655	-840.281	105.23
d	5	6	7	8
ΔC_2	-1282.806	538.18	-1282.806	105.23
d	9	10	11	12
ΔC_2	-840.281	95.654	-1282.806	547.756

By the previously mentioned condition intial state of all electric vehicles are full charged, and returning to this state again is viewed as a circle. The grid company's earnings in the circle as shown in table 5、6, but all reflect the effectiveness of grid company of negative growth trend.

6.Conclusion

In the exisiting peak-valley TOU power price mode, electric vehicles's charging and discharging behavior is preliminarily discussed and obtains the following conclusions: using the electric vehicles reduces the driving costs even have the additional incomes; Played a certain role in the regulation of peak load but not obvious;the cost of purchasing electricity from the electric vehicles is too high, the total benefit presents the negative growth tendency.

This paper only considers that electric vehicles charge in valley period and discharge in the peak period, and then the model should be combined with the flexibility in the deep step. The distribution of electric vehicles' load should be Coordinated with conventional power and load. As for framing the charging and discharging price should really consider the balaned interests between electric vehicle owners and grid company.

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